
Interactive comment on "Exchange of CO2 in Arctic tundra: impacts of meteorological variations and biological disturbance" by Efrén López-Blanco et al. Anonymous

Referee #1

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Lopez-Blanco and colleagues present a study of ecosystem CO2 dynamics across eight snow-free seasons for a wet fen tundra ecosystem in west Greenland. The authors compare ecosystem respiration (Reco) and gross primary production (GPP) with key climatic drivers to characterizes how ecosystem CO2 dynamics will change with climate. Comparisons are made at hourly, daily, and seasonal timescales to understand how drivers of ecosystem CO2 dynamics change across temporal scales. Additionally, the authors compare several eddy covariance partitioning methods in order to assess uncertainty associated with interpretation of EC derived estimates of Reco and GPP. The main finding is that large interannual variations in Reco and GPP with climate are compensatory, and so net ecosystem exchange (NEE) of CO2 remains quite stable across climatically diverse snow-free seasons. This is a valuable analysis of a fairly long EC data set, particularly for a tundra ecosystem. Overall I find the methodology to be quite sound and recommend several relatively minor but important revisions before the manuscript is considered further for publication. The following paragraphs describe more major issues, and are then followed by specific comments.

We thank the reviewer for taking the time to assess our manuscript. We believe the comments have improved the manuscript.

The introduction should be improved in several ways. First, the paragraph on flux partitioning seems out of place. The first and third paragraphs highlight research surrounding tundra/Arctic C cycling, and are bisected by the paragraph on partitioning. It would make more sense to first discuss carbon cycle dynamics and then highlight challenges associated with EC partitioning; so switch paragraphs two and three.

The reviewer is correct that the paragraphs 2 and 3 should be inverted. The introduction has been modified based on the referee comment.

In the results it seems that sections 3.3 should come before section 3.2; first describe the partitioning comparisons and then get into the results. Related, I don't see where you mention which partitioning/gapfilling methods you report. It would make sense to first present the flux processing results, and then state which date you'll present moving forward. Also, it is general good to have the figures ordered as they appear in the text. Currently order is Fig 5 -> Fig 4 -> Fig 3.

The reviewer is correct that the sections 3.2 and 3.3 should be inverted. The results section has been improved. Now the partitioning/gapfilling method is presented before the results (L224-241).

Further, the figures have been ordered as they appear in the text.

The last major area for revision is related to the broader implications of your results – specifically, how transferable are they? There is some of this in section 4.3, but it could be expanded there, and perhaps in section 4.1. Specifically, it occurs to me that this research site receives a relatively high amount of precipitation relative to many other tundra ecosystems, and has no permafrost. As such, the NEE responses to climate at other tundra sites may likely be more variable. It would be worth discussing this a bit further.

Text has been revised and implemented to focus on the implications of our results (L335-342):

> This site likely receives more precipitation relative to many other tundra ecosystems, and has no permafrost, thus the NEE response to climate could be less variable. However, Kobbefjord is located in a costal area, so it is not surprising to receive high precipitation, and other ecosystems such as coastal blanket bogs (Lund et al., 2015) often receive even more precipitation, without a clear impact on the NEE sensitivity. On the other hand permafrost adds another layer of complexity to the C dynamics. Although some studies showed similarities of CO_2 fluxes in various northern wetland ecosystems with and without permafrost (Lund et al., 2015), permafrost has strong influence on the hydrology of peatlands, and therefore their topography and distribution of vegetation. Especially in the context of climate warming permafrost thaw can cause large changes to the ecosystems.

Secondly, it is difficult to talk about ecosystem CO2 source/sink dynamics without some discussion of non-growing season processes. Papers by Zona et al and Commaine etal (very recently) indicate the importance of non-growing season C dynamics. Also, given the fact that you are using net sink timing to define the growing season, I wonder what effect previous growing season or previous winter conditions might have on your results? For example does a wet summer followed by a warm winter lead to high Reco the following year? There are very likely some interesting time-lag effects influencing the patterns you observe. Again, you allude to these processes, for example, by mentioning previous winter temperatures, but I think a more targeted and thoughtful discussion on temporal lags/dynamics would be useful. Actually, it would be helpful to report non-growing season climate data, and perhaps even analysis of these sorts of time lags. I do not think the latter is absolutely necessary, because this paper already contains a lot of information, but it could be informative either here or in another paper.

Graph 2b has been included and the corresponding text in the results section has been revised to include meteorology from non-growing season, including preceding cold season (October to May) and warm season (June to September) (L208-212).

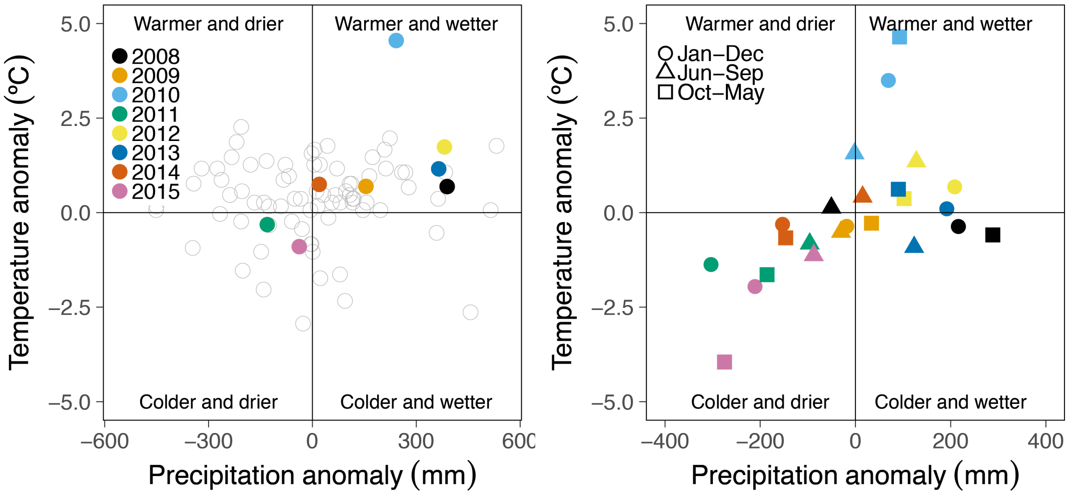

Figure 2: (a) Annual Temperature (°C) and precipitation (mm) anomalies of the analyzed years (2008-2015) compared to the 1866-2007 time series shown as empty circles (Cappelen, 2016), and (b) within the 2008-2015 period including annual (January to December), warm season (July to September) and cold season (October to May) averages.

Among the eight study years (figure 2b), the warm season (June to September) temperature and precipitation anomalies ranged from approx. -1°C (2011, 2013 and 2015) to +1.5°C (2010) and -96 mm (2011) to approx. +125 mm (2012 and 2013), respectively. The cold season (October to May) anomalies have shown a significant increase of both temperature and precipitation variability. 2010 was the warmest year while 2011 and 2015 were the coldest years.

Moreover, some text has been implemented in the discussion l368-379

The year 2010 had the warmest mean annual temperature (3.4 °C compared to the -0.4 °C 2008-2015 mean) and the warmest mean wintertime temperature (-2.7 °C compared to -6.79 °C 2008-2015 mean)(Figure 2a). These climatic conditions stimulated the thinnest (snow accumulation of 142 m compared to averaged 567 m)(Table 1)** and shortest-lasting snowpack. Consequently, 2010 had the longest growing season (85 days) and very high growing season C uptake (-70 g C/ m^{-2}). Increases in temperature can lead to high respiration rates during early winter (Commane et al., 2017; Zona et al., 2016), but also during the following summer (Lund et al., 2012), which is related to soil temperature and snow dynamics. Kobbefjord had in 2011 one of the coldest mean annual temperature and mean wintertime temperature (-1.7 and -6.1°C respectively), which created the thickest (snow accumulation of 995 m) and the longest-lasting snowpack, stimulating the shortest growing season (only 47 days). According to Lund et al. (2012), below thick snowpack soils will be insulated from reaching low temperature; and at the same time the snowpack will act as a lid by increasing diffusive resistance, preventing R_{eco} from being released to the atmosphere. After snowmelts, CO_2 stored in soil and snow cavities will be released.

**Table 1 has been implemented with snow accumulation (instead of maximum snow depth).

Further, we understand the referee point about the importance of non-growing season climate implications. Winter fluxes are beyond the scope of this paper, since it is hard to analyse only eight-years dataset, but that an ongoing modelling effort will seek to address these issues. The referee comment will be a good point to address in this coming paper.

(I will also note here that it seems odd to place the section on EC processing between to two sections discussing CO2 dynamics).

The sections have been inverted accordingly.

Minor edits:

- *Lines 40-44: You should explicitly state that you are referring to soil C stocks – this doesn't come until the very end.*

  Now corrected.

- *Line 76: Why do you mention C a need for sites with C stocks if you don't present them in the paper?*

  Although it is highly interesting to measure C stocks in the field, the reviewer is correct that we don't present C stocks data in this paper. Therefore, we decided to remove this part.

- *Line 102: This line is a bit too informal; it's not Skip's map, it was a large collaborative effort. It would be more appropriate to report the class and the name of the map and the paper describing the map. Walker, D. et al. (2005), The Circumpolar Arctic vegetation map, Journal of Vegetation Science, 16(267-282).*
- *Lines 103-104: I don't understand this, what does it mean that the site 'went out of the Arctic zone'?*

  Both parts have been adjusted accordingly l 99-103:

  Kobbefjord belongs to the "Arctic Shrub Tundra" (bioclimate zone E) according to The Circumpolar Arctic Vegetation Map (Walker et al., 2005; CAVM Team, 2003). This map is based on the summer warmth index (SWI), which is the sum of the monthly mean temperature above 0 °C from May to September, and the southernmost bioclimatic zone E has the limits 20-35. In 2010 and 2012, climate conditions led the area to experience temperatures from warmer climatic zone (SWI ca. 36 and 35 respectively).

- *Line 142: What is Papale et al In Prep? Perhaps indicate that this is via personal communication as well, if that is the case.*

  Reference deleted.

- *Line 264: This is a very simplistic and incomplete view of the residence time of fixed C. I'm not sure you can say anything meaningful about C residence time* *with discussing fluxes between pools and storage, which aren't really addressed in this manuscript.*

Net flux information alone is not enough to determine residence times, which depend on internal flows, dynamics and pool sizes. So we adjusted this text to remove the discussion around residence times.

- *Line 279: This could be worded clearer; at first I thought you were saying the PAR values peak at 6am, which was confusing. Perhaps explicitly state that the predictive importance of PAR peaks at this time.*

  Sentence adjusted accordingly, "coinciding with the predictive importance of PAR"

- *Line 287: The model 'catching' something is perhaps a bit too colloquial. Better to state that it revealed or indicated a decline in the importance of PAR in 2011.*

  The text has been changed to "the Random Forest analysis revealed a decrease of PAR's importance in 2011"

- *Line 295: You can only say that NEE is insensitive to climate during the snow-free season.*

  Sentence implemented.

- *Line 300: 'NEE exchange' is redundant, just use NEE (here and elsewhere).*

  Corrected.

- *Line 330: Lots of typos here.*

  Thanks for finding these two errors; now corrected.

- *Figures 4 & 7: It would be good to include a legend indicating what the colors represent, in addition to the text description.*

  The legend has been updated in both Figure 4 and 7. In Figure 4, the facets' labels on the right have been increased in size as well for readability purposes. Moreover, it has been modified the colours of air temperature and precipitations, as well as the direction of the facets on the right. Further, Figure 6 has been also harmonized colour wise with respect Figure 7.

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